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# Neurogoggles for Stroke Rehabilitation

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*Introduction:* Stroke is a major cause of disability across the globe, leaving survivors with severe motor and cognitive impairments and reducing their participation in the society. It has been widely advocated that early acute rehabilitation exploits the unique neuroplasticity conditions that exist in the first weeks after brain injury, and results in improved motor recovery [1]. However, rehabilitation onset is often delayed and delivered at suboptimal intensities due to the limited motor capabilities in the acute phase. Proven cognitive neuroscience principles such as action observation/execution, mirror therapy, graded/guided motor imagery and kinesthetic motor imagery training are particularly appropriate to promote the early activation of neural structures involved in the recovery process. Additionally, there is emerging clinical evidence on the effectiveness of motor imagery training using a brain-computer interface (BCI) combined with virtual reality (VR) [2]. To this end, we aim to develop a wearable device that equips BCI and virtual/augmented reality (VR/AR) technology, representing a versatile tool to bring these treatment modalities to the neurorehabilitation field.

*Material, Methods and Results:* We developed a neurogoggles system that integrates motion tracking (arms, hands, fingers and objects in the environment), electrophysiological measurements (32 gel-based active EEG, 8 active EMG, 5-lead passive ECG) and a head-mounted display (HMD) onto one single portable platform (Fig. 1). The system synchronizes multimodal inputs with millisecond precision and processes them in real time to provide appropriate VR/AR feedback. Importantly, the system also provides outputs for biofeedback devices such as functional electrical stimulation (FES), haptics and robotics for facilitating the training of the cortico-spinal pathways.

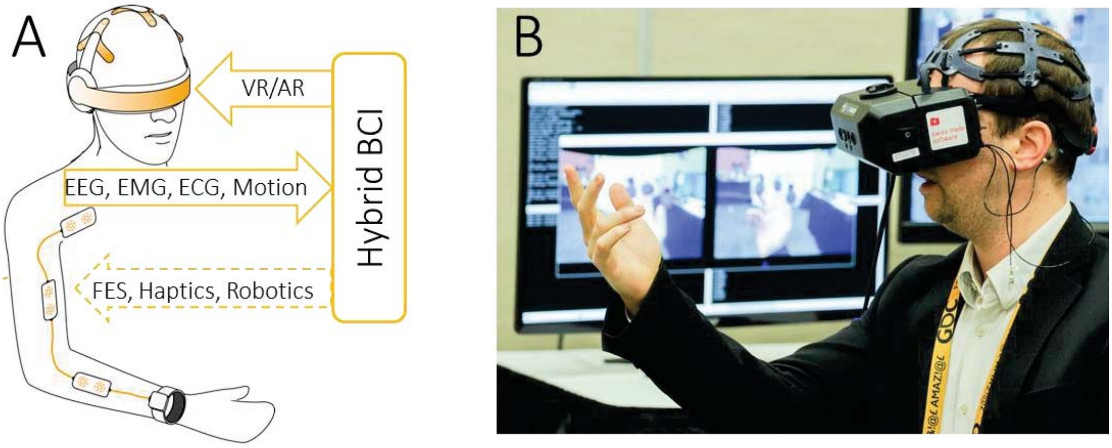


*Figure 1. (A) Functional schema of the hybrid BCI system; (B) Neurogoggles prototype (with detachable HMD)*

*Discussion:* The immersive VR feedback provided by the neurogoggles offers exercises that empower the application of action observation/execution training, virtual mirror therapy (movements of the non-paretic arm are translated to the paretic side of an avatar), and motor imagery training. These training strategies enable early intervention, even in case of the severe disability. In addition to VR, the system also offers AR for later stages of the rehabilitation process that enables the interaction with virtual objects in the real world and thus enriches the training quality. Additionally, these feedback modalities can be gamified to maximize motivation and increase training dose.

*Significance:* The presented neurogoggles opens new avenues for research in multimodal strategies for effective motor rehabilitation in stroke and other neurological conditions (e.g., phantom limb pain, brain trauma, multiple sclerosis, and spinal cord injury).

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